

# Well Passivated a-Si:H Back Contacts for Double-Heterojunction Silicon Solar Cells

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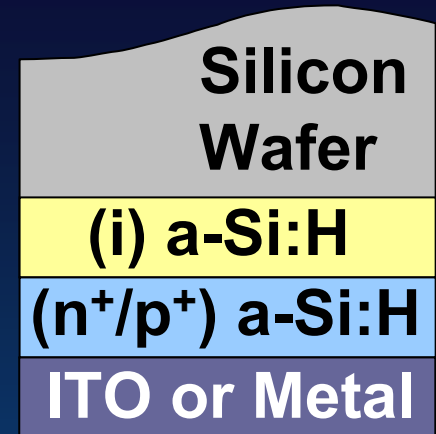
Hilton Waikoloa Village, Waikoloa, Hawaii

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# Outline



- ⇒ Advantage of doing back contact with Silicon Heterojunction (**SHJ**)
- ⇒ Hot-Wire CVD (**HCWCVD**)
- ⇒ SHJ back-contact better than alloyed/diffused
  - both n- and p-type wafers
  - good back-surface-field (**BSF**)
- ⇒ Critical for good SHJ solar cell fabrication
  - layer optimization- **in brief, here**
  - **surface preparation**

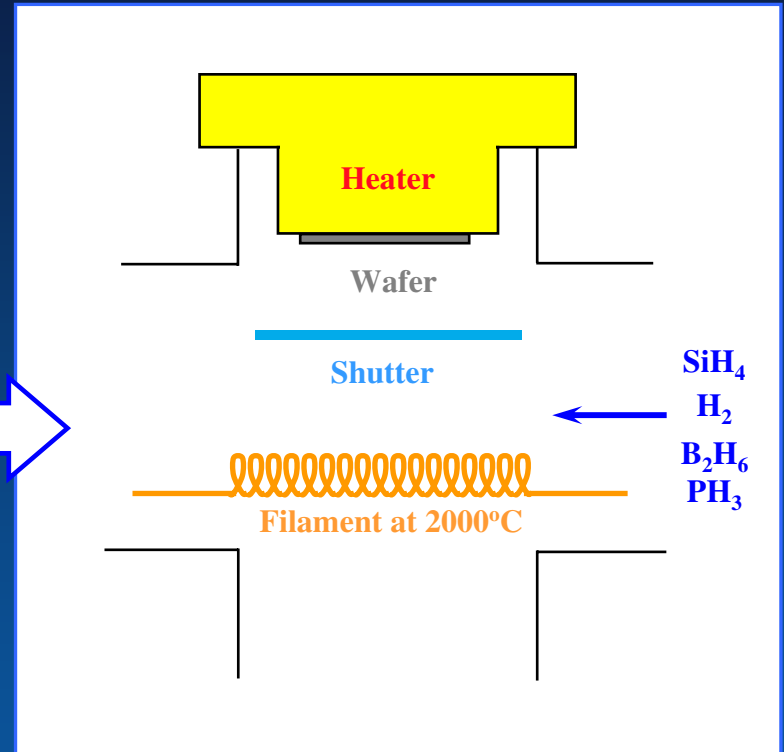
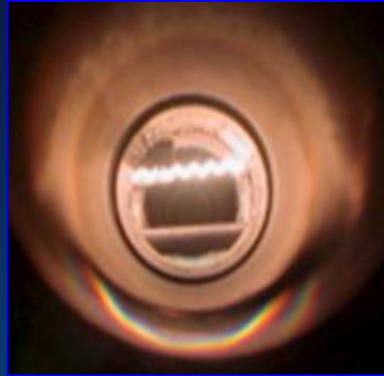
# Advantages of a-Si:H/c-Si Heterojunction

- ⇒ Low temperature processing ( $< 250^{\circ}\text{C}$ )
  - preserves high lifetime
  - compatible with gettering or hydrogenation
  - prevents bowing ( $< 200\mu\text{m}$  wafers)
- ⇒ Excellent passivation on c-Si
  - LOW minority-carrier recombination velocity
  - HIGH open-circuit voltage ( $V_{oc}$ )
- ⇒ a-Si BSF better than alloyed or diffused BSF
  - both passivation and vertical current conduction
  - no direct metal/c-Si contact (**impurity source**)

# Advantages of Hot-Wire CVD

⇒ HWCVD

- simple
- scalable
- fast deposition
- no ion bombardment of c-Si surface



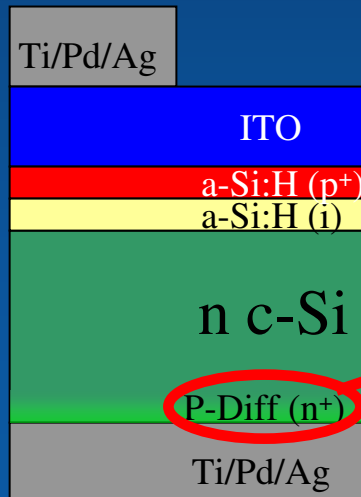
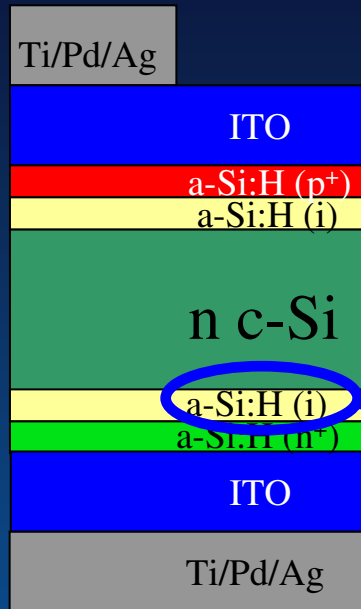
Plasma damage to c-Si a major issue using PECVD

# Optimization of SHJ Devices

⇒ Critical: 1. preparation, 2. deposition

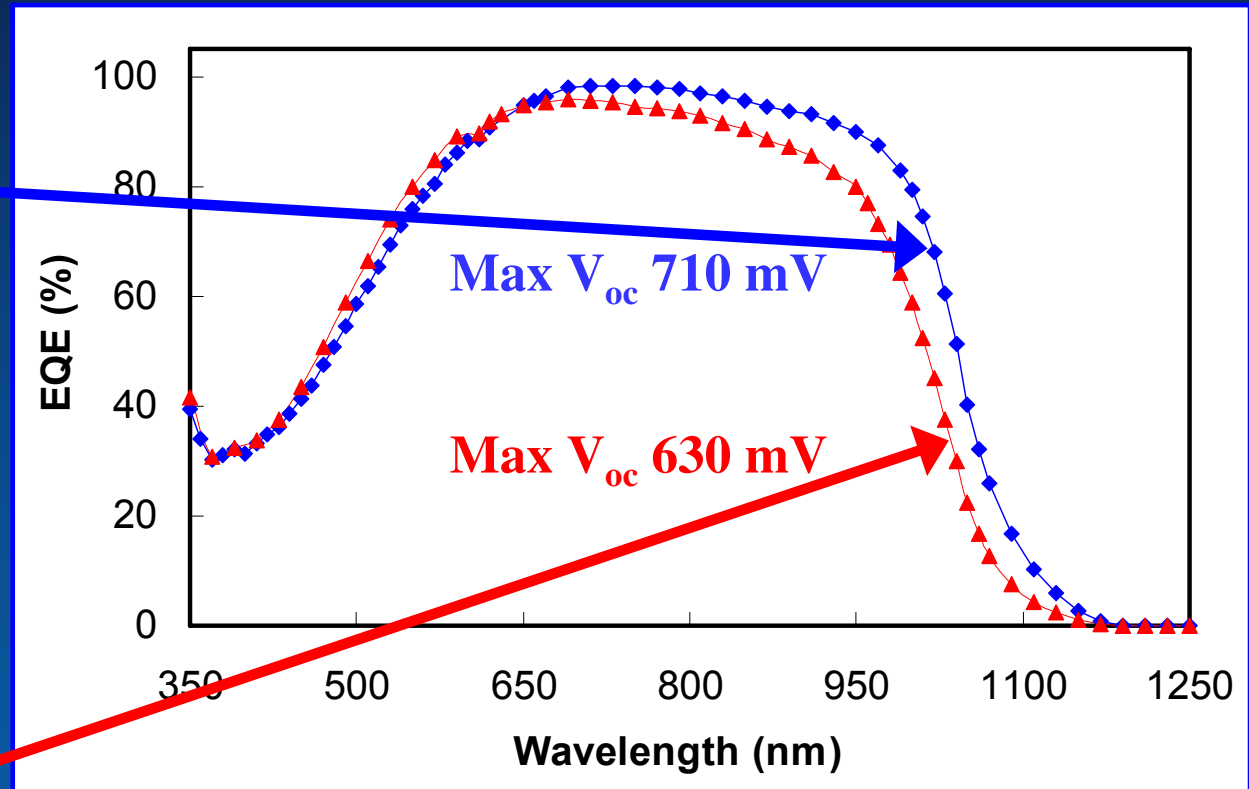
- 1. Very clean SHJ interface preparation ( $V_{oc}$ )
  - stringent cleaning before a-Si:H deposition
  - junction and contacts close to interface
- 2. High quality intrinsic and doped a-Si:H
  - no epitaxy at interface ( $V_{oc}$ )
  - low interface defect density intrinsic a-Si:H ( $V_{oc}$ )
  - high dopant activation in emitter and BSF ( $V_{oc}/FF$ )
  - low blue absorption in a-Si:H ( $J_{sc}$ )
  - good front/back contacts to ITO/metal ( $FF$ )

# SHJ Back-Contact Passivation (n-type FZ)



**Phosphorus Diffused** vs. **SHJ/ITO**

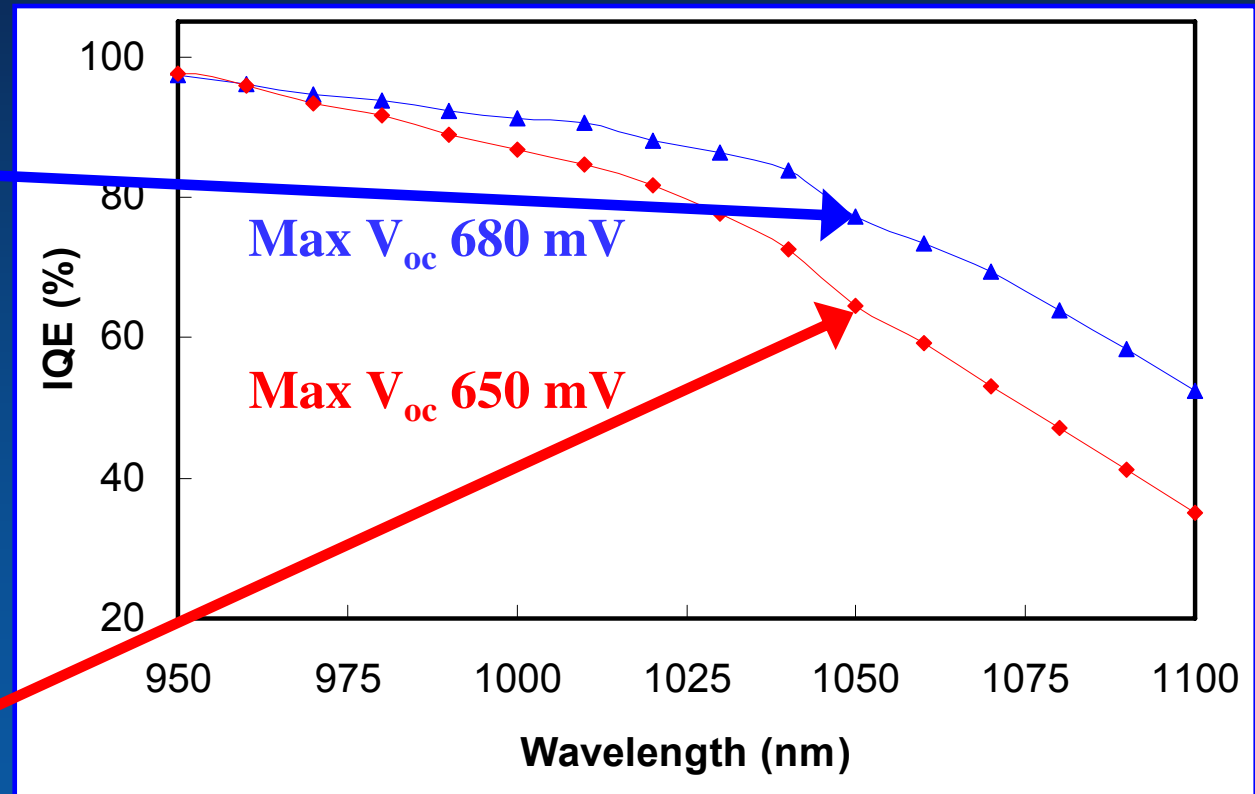
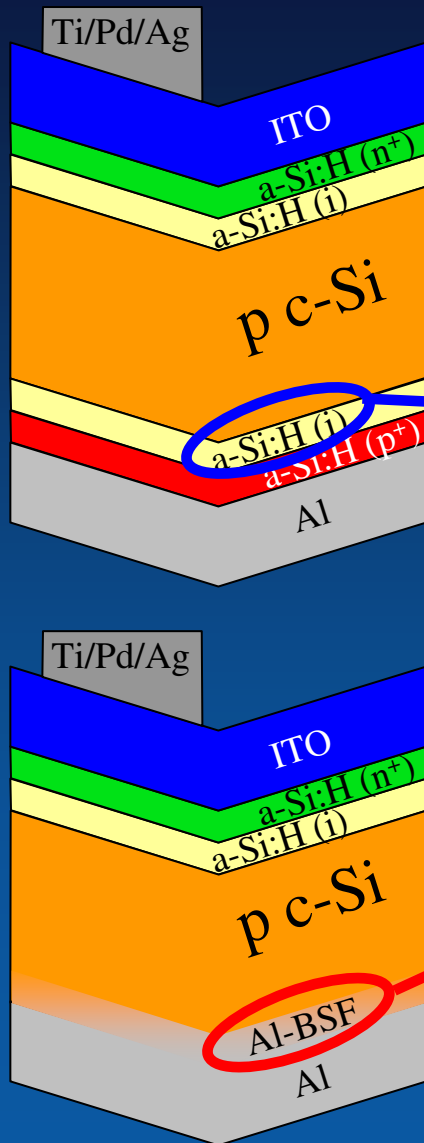
**Absolute External Quantum Efficiency**



# SHJ Back-Contact Passivation (p-type FZ)

**Alloyed Al-BSF** vs. **SHJ/Al**

Absolute IQE- removing reflectance of front





# SHJ Back-Contact is Excellent

⇒ SHJ better than Al-BSF on p-type wafer

- superior back surface passivation
- Fill-Factor greater than 78% achieved
- minority-carrier recombination velocity

vs. 

- 15 cm/s for SHJ ⇒ (i/p) a-Si:H/Al
- 1000 cm/s for Al-BSF

⇒ SHJ better than Phosphorous diffused on n-type

- superior back surface passivation
- Fill-Factor greater than 74% achieved

⇒ SHJ interfaces are more critical than alloyed or diffused junction surfaces

# Surface Preparation Important

## ⇒ 4 Generations (GEN-1 through GEN-4)

- increasing complexity
- developed for SHJ
- baseline deposition for each GEN's maximum  $V_{oc}$

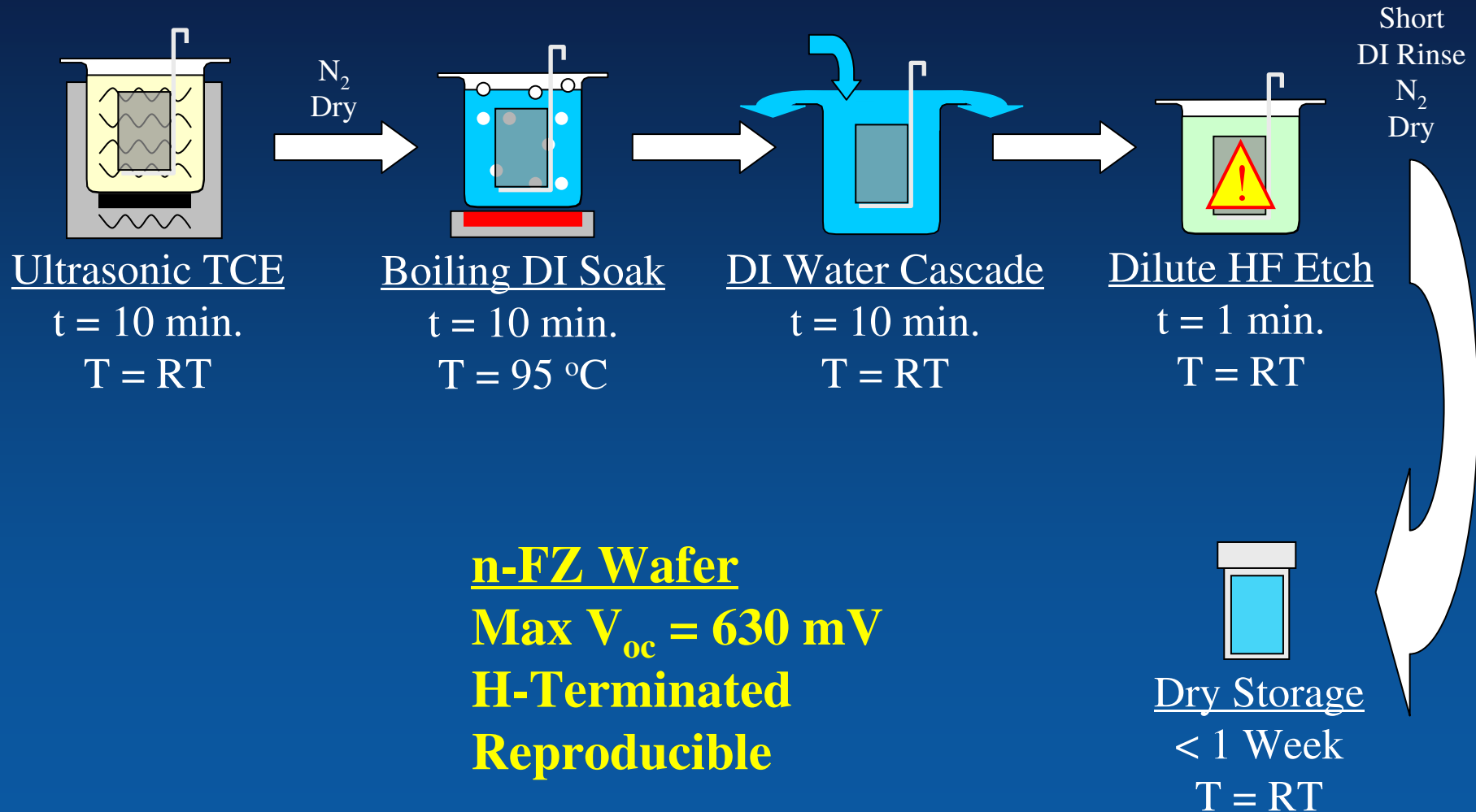
## ⇒ Stable oxide and interface

- store in clean box
- remove impurities trapped in oxide by final HF etch

## ⇒ Protective chemical oxide by RCA-2

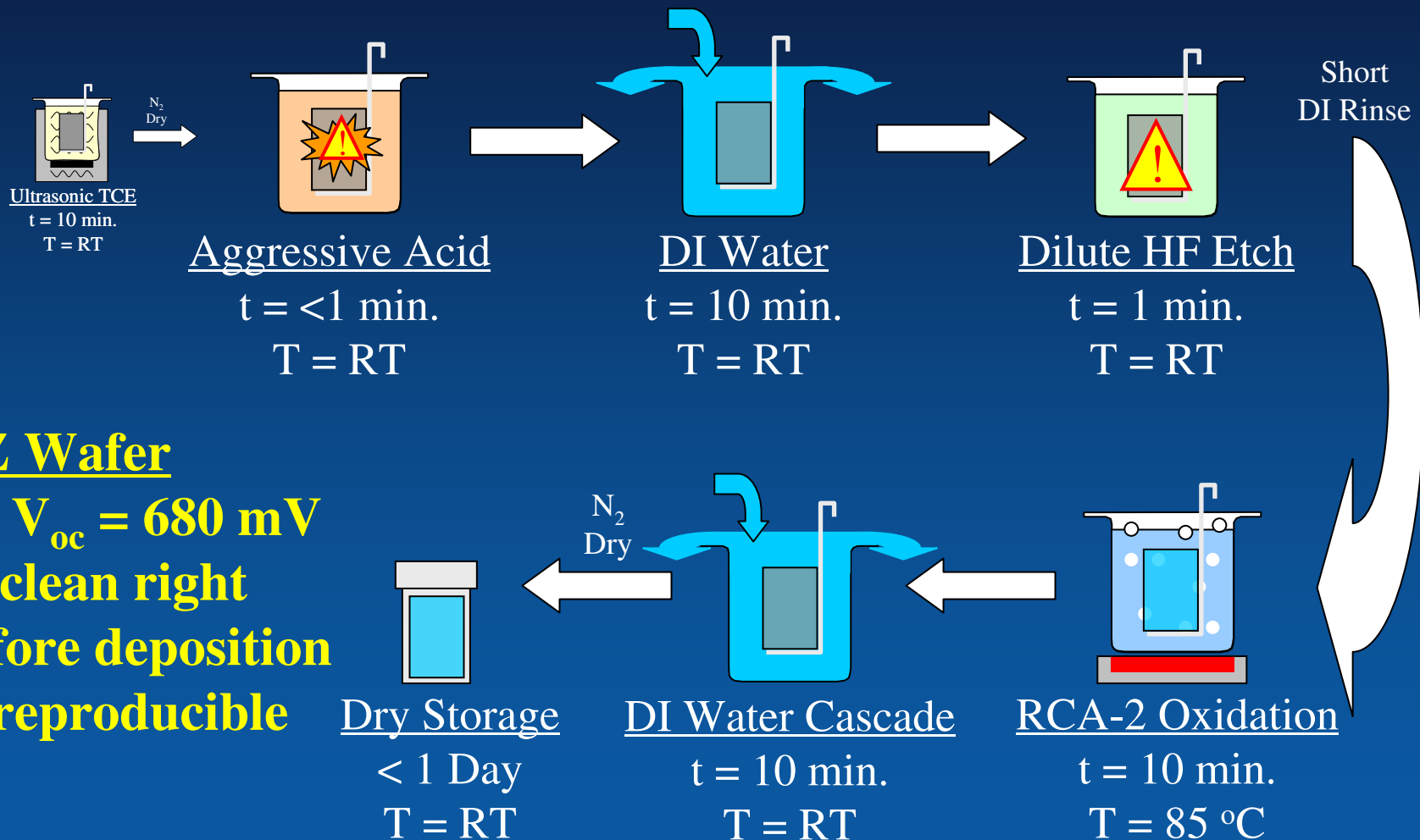
- 6:1:1 ⇒  $H_2O : HCl : H_2O_2$
- 2.5% HF strip before deposition

# GEN-1 Simplest Cleaning Procedure



# GEN-2 Aggressive Acid Cleaning

## Replaced Boiling DI Water



## n-FZ Wafer

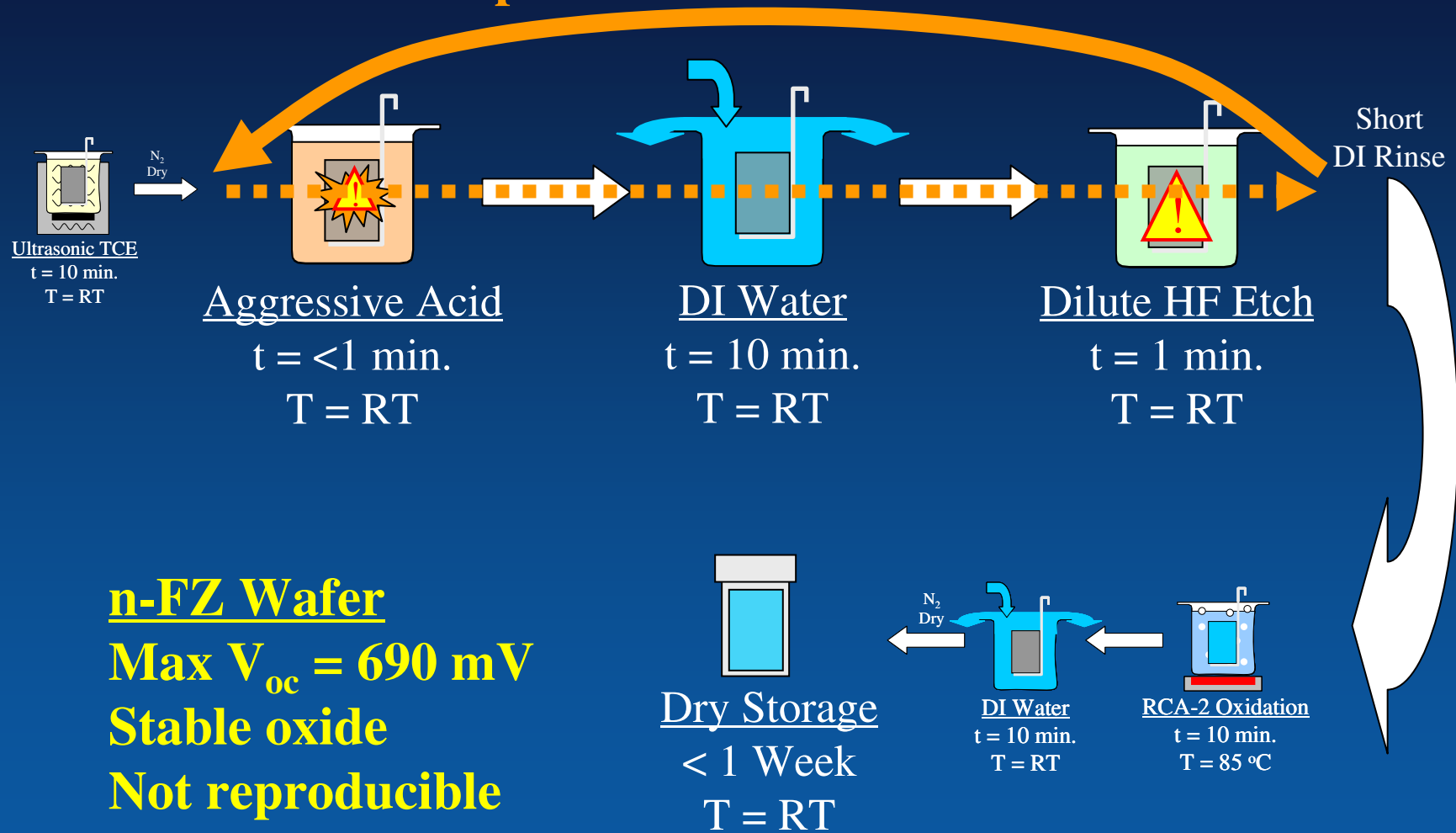
Max  $V_{oc} = 680$  mV

Full clean right  
before deposition

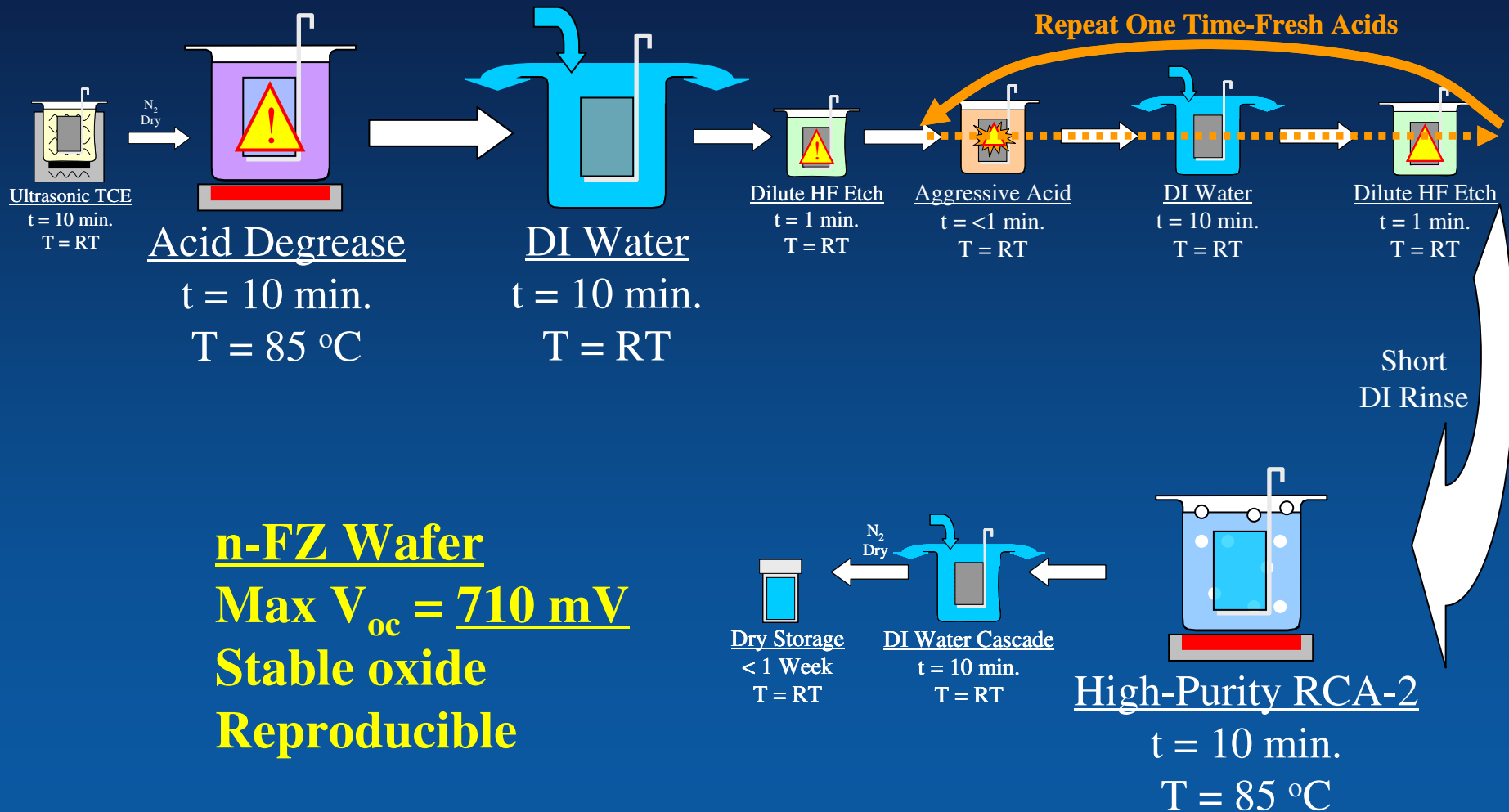
Not reproducible

# GEN-3 Repeat Aggressive Acid Cleaning

Repeat One Time-Fresh Acids



# GEN-4 Improved Degrease and Oxide Purity



# Surface Preparation Summary

## GEN-1 Simplest

- H-terminated

## GEN-2 Aggressive Acid Cleaning

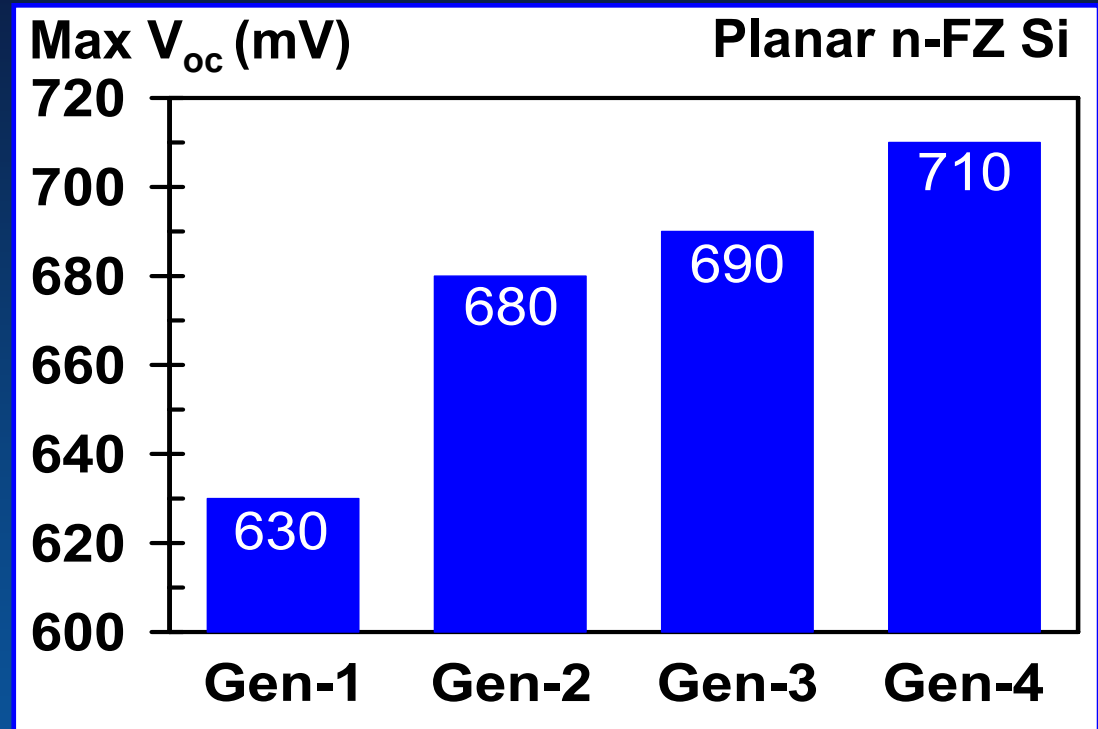
- just before deposition
- not reproducible

## GEN-3 Repeated Aggressive Acid

- degrease interaction
- not reproducible

## GEN-4 Improved Degrease & Oxide Purity

- reproducible
- stable chemical oxide

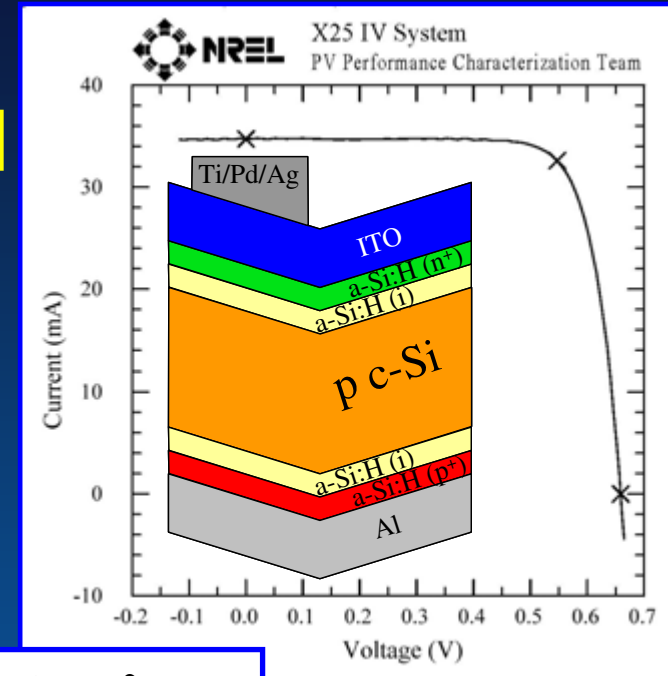


# Conclusions

⇒ **SHJ successfully replaced** Al-BSF or P-diffused full area back contacts

⇒ **Surface preparation and a-Si:H optimization** are both critical for device performance

⇒ **Confirmed Efficiency**  
➤ **18.2 %**



AM1.5 1-cm<sup>2</sup>

$V_{oc} = 667 \text{ mV}$

$J_{sc} = 35.5 \text{ mA/cm}^2$

$FF = 76.9 \%$

$\eta = 18.2 \%$

ISO-9000 AM1.5  
Light I-V measured  
by Keith Emery &  
Tom Moriarty



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